DOCUMENT RESUME

ED 163 068 TM 008 147

AUTHOR Lutz, Kathryn A.
TITLE The Implications of Brain Research For Learning Strategies and Educational Practice.
PUB DATE 3 Aug 78
NOTE 30p.

EDRS PRICE MF-$0.83 HC-$2.06 Plus Postage.
DESCRIPTORS Cerebral Dominance; Cognitive Processes; *Cognitive Style; Creative Thinking; Educational Improvement; Intelligence Factors; *Lateral Dominance; *Learning Activities; Logical Thinking; *Neurological Organization; *Thought Processes

ABSTRACT

Research involving split-brain patients has shown that the two hemispheres of the brain process information differently. The left side of the brain is more analytical, the right side is more holistic, taking in overall characteristics rather than specific detail. This reserach can be applied to the educational process in several ways. The concepts of learning and creativity can be enlarged to include right-brain thinking and mental abilities. Learning and creativity can be facilitated by using learning strategies that activate the lesser-used right side of the brain. These strategies include imagery, pictures, chunking, and analogies. Since evaluating only the verbal and analytical outcomes of learning may fail to reveal the full effects of instruction, brain laterality considerations should have an impact on curriculum development, as well as the evaluation of instructional effectiveness and learner achievement. (Author/JAC)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED163068

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL NATIONAL INSTITUTE OF EDUCATION POSITION OR POLICY

THE IMPLICATIONS OF BRAIN RESEARCH FOR LEARNING STRATEGIES AND EDUCATIONAL PRACTICE

by

Kathryn A. Lutz

University of Southern California

August 3, 1978

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY

Kathryn Lutz

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC) AND USERS OF THE ERIC SYSTEM."

TM008 147

Abstract

Primarily through the research done on split-brain patients, it was discovered that the two hemispheres of the brain process information differently. While the left side is more analytical, the right side is more holistic, taking in overall characteristics rather than specific detail. This research can be applied to the educational process in several ways. The concepts of learning and creativity can be enlarged to include right-brain thinking and mental abilities. Learning and creativity can be facilitated by using learning strategies that activate the lesser-used right side of the brain. These strategies include, for example, imagery, pictures, chunking, and analogies. Finally, brain laterality considerations should impact the process of curriculum decision making and evaluation of instructional effectiveness and learner achievement.

The Implications of Brain Research for Learning Strategies and Educational Practice

Through the research done on split-brain patients, it was discovered that the two hemispheres of the brain process information differently. While the left side is more analytical, the right is more holistic, taking in overall characteristics rather than specific detail. This research can be applied to the educational process by a) re-conceptualizing learning and creativity in light of brain laterality, b) facilitating learning and creativity by activating the lesser-used right side of the brain, and c) considering brain laterality during curriculum and evaluation decision making. After a brief overview of the research on brain laterality, each of these three areas of application are discussed.

Research on Brain Laterality

Two Ways of Thinking. The research on brain laterality has confirmed what teachers have probably observed for years--namely, that people can process information in two complementary ways including logical-analytical and analogical-synthetic. Consider the following descriptions of sand that I once read by two of my third-grade students: "Sand is made of silica, which is silicon dioxide SiO_2" and

> "Big rock into pebbles,
> pebbles into sand.
> I really hold a million,
> million rocks here in my hand."

One difference between these two descriptions is that the first pro-

bably was copied from a book. The more interesting difference, however, is that the first response is a logical, analytical description of sand while the peom is an intuitive, metaphorical response. Which description of sand is the better or the more correct one? Although I probably favored the logical response at the time, I now know that the responses are different but equally "correct." They represent two alternate ways of thinking about sand, one way dominated by the left hemisphere and the other way dominated by the right brain.

In a recent book discussing brain laterality and education (Wittrock et al., 1977), the left side of the brain is described as the analytic, deductive, sequential, specific, logical, and verbal processor. The right hemisphere, on the other hand, is termed the synthetic, inductive, simultaneous, gestalt, and visual processor. This dichotomy of brain function has commonly been equated to the visual-verbal dichotomy. However, classifying the right brain as the picture processor and the left brain as the verbal processor is a misleading over-simplification. Although the left hemisphere often dominates for verbal processing and the right brain dominates for picture processing, the important distinction is that the two sides of the brain are specialized for the <u>way</u> that they process information rather than for the <u>type</u> of information (i.e. pictures of words) that they process. A person can use the left hemisphere to analyze a picture and use the right hemisphere to make verbal analogies. The left hemisphere analyzes incoming information for specific detail while the right side sees the overall picture and general characteristics.

Both ways of thinking are important for learning.

Research with Split-brain Patients. Much of the experimental evidence on brain laterality comes from studies of patients who have had the two sides of the cortex surgically separated to prevent epileptic seizures. The surgery prevents the seizure from transferring from one hemisphere to the other via a bundle of nerve fibers called the corpus callosum which connects the two brain hemispheres and serves as the communication channel. When these fibers are severed, information such as words and pictures cannot be channeled between hemispheres so that each hemisphere can be studied in isolation from the other.

Due to the "crossed wiring" between brain and body, the right hand of the split-brain patient is controlled by the left hemisphere while the left hand is controlled by the right hemisphere. Experiments with these patients indicate that right-handed patients were unable to draw as well with the right hand as with the left but their ability to write with that hand was not impaired. When asked to draw and write left handed, they were able to draw but not write. Their ability to copy words with the right hand indicates that the left hemisphere controls verbal tasks while their ability to draw with the left hand indicates that the right hemisphere controlls spatial tasks.

Other experiments with split-brain patients better indicate the functions of each hemisphere. Since the two hemispheres cannot communicate in a patient whose corpus callosum has been severed, an experiment can be devised in which one picture or word is relayed

to one side of the brain while a different picture or word is relayed to the other side. Several researchers conducted such a study using a set of pictures of different faces including, for example, a young boy and a woman wearing glasses. The researchers cut the pictures in half down the center of each face and made a set of photos called "chimeric stimuli", which consist of the halves of two different faces. The reconstructed photos were shown to the split-brain patients so that the left half of each photo was perceived only in the right hemisphere and the right side of each photo was relayed only to the left hemisphere.

The results of that experiment clearly indicate that the left hemisphere is analytic while the right hemisphere perceives the gestalt. When the patients were asked to verbally describe the photo, they described the features of the face that was on the right side and thereby perceived by the left hemisphere. For example, if the right half was the woman with glasses, the patients mentioned the glasses, long hair etc. However, when the patients were asked to point to the picture that they just saw from the original group of photos, they pointed to the face corresponding to the half-face on the left side and thereby perceived in the right hemisphere. For example, they pointed to the boy's face. Amazingly, the patients did not realize that they had seen two different halves rather than the one face that they later described or pointed to. When a spatial-gestalt response was required (pointing), the face perceived by the right hemisphere was reported. When a verbal-analytical response was required (naming

the features), the face perceived by the left hemisphere was reported. These results are striking evidence that both sides of the brain can process pictures but they do so in different ways--one analytical and one gestalt.

Normal Brain Laterality. Although the evidence is compelling that the two sides of the brain function differently when they are isolated and unable to communicate in the split-brain patient, does this functional difference remain in the normal person? There is a good deal of evidence to believe that brain laterality does exist in the normal, connected brain to some extent. One method of determining the lateral functioning of the brain is to examine the electroencephalogram (EEG) during various tasks. Studies show that during reading the EEG shows a shift of activation to the left hemisphere while picture viewing and mental visualization elicit more activity in the right hemisphere.

Another indication of lateral specialization in the normal brain is the direction of certain lateral eye movements while thinking. Thinking or brain activation that is centered in one hemisphere is thought to cause eye movements contralateral to that hemisphere. A number of studies indicate that initial eye movements are usually to the right after verbal questions and generally to the left following questions requiring spatial visualization. These results provide further evidence that the two sides of the brain specialize in different ways of thinking.

It should be noted again that laterality is not necessarily task

specific--that is, verbal and pictorial tasks do not always elicit more left or right hemisphere processing respectively. The hemisphere which becomes more activated depends also on the situation and the individual. Music, for example, is usually perceived more by the right hemisphere than by the left, but musicians are able to analyze music using the left hemisphere. The point is that the left hemisphere is dominate for thinking of an analytical nature while the right hemisphere is dominant for holistic thinking.

Re-conceptualizing Learning and Creativity

Learning and Mental Abilities. Learning and mental abilities must be re-conceptualized in light of brain research on laterality. Defining learning and ability solely in terms of performance on verbal tests and logical reasoning tests is invalid because another realm of learning outcomes and mental abilities exist related to the right hemisphere. The concept of mental abilities, for example, should be expanded to include right hemisphere skills such as synthesizing ability and mental visualization ability. One test that can be used to assess synthesizing ability is a gestalt figure-completion test such as the Street test. The test consists of a set of silhouette pictures that are partially omitted. The objective is to identify each picture from the few parts of it that are shown. Correctly identifying the picture requires the ability to see how seemingly unrelated parts go together to make a whole.

Just as there are individual differences in left-hemisphere

abilities such as verbal ability and logical reasoning, people also differ in their ability to synthesize and visualize. Having high ability in one realm does not insure high ability in the other. In fact, some studies have shown that people tend to favor one mode of thinking over the other and are often better at one type of thinking than the other. For example, several researchers compared the performance of a group of lawyers and a group of ceramicists on a number of tests ranging from a standardized verbal intelligence test to a word-picture preference test. They found that the lawyers were better at verbal and analytic tasks than they were at spatial-visualization tasks while just the opposite pattern was found for the ceramicists. The participants also preferred the mode of thinking that they were better at. The abilities and preferences of learners should be an important consideration in instructional decision making.

The concept of learning should also be expanded to consider learning outcomes other than those assessed by a traditional, verbal retention test. Evaluating other types of learning outcomes will be discussed in the section on Evaluation.

Creativity. In light of the evidence of brain laterality, both self-reports by creative individuals and experimental studies of creativity suggest that right hemisphere thinking is a central and crucial part of the creative process. Right hemisphere thinking activities such as mental imagery and gestalt perception are commonly reported by creative people (Vernon, 1970).

Mental imagery plays a crucial role in creativity according to

many creative individuals. Einstein, who is probably mankind's greatest thinker, reported his reliance on mental imagery rather than on words or language during his thought. Kebule discovered the benzene ring through a vision of a series of atoms linked in a chain and biting its tail like a snake. Michael Faraday, the father of field theory, "visualized" the electric and magnetic lines of force. One contributor of inventive ideas named Walkup did a study of creativity in his co-workers at a large industrial research institution. He concluded that creative persons have the ability to visualize in the area in which they are creative.

Gestalt perception is another major thought pattern reported by creative individuals. They say that ideas come to them "all at once" and seem to be outside the realm of conscious thought or effort. Mozart, the great composer, for example, reports that he does not imagine a musical piece in successive parts or component sequences but rather he envisions the whole piece all at once, almost "complete and finished" in his mind. Another great composer, Tchaikovsky claims to "invent the musical idea and the instrumentation simultaneously." (He goes on to stress that getting the idea worked out into the proper final form requires effort; the piece must be critically examined, improved upon, extended etc. before it becomes the finished creative product.)

Music is not the only area in which creative individuals report that their inspirations occur holistically and almost without cognitive effort (perhaps they mean left-hemisphere effort). The great poet,

Stephen Spender, describes writing poetry as requiring a very different kind of mental effort than the type that one usually associates with mental work. He says he "is aware of all the implications and possible developments of his idea" when he writes. This description sounds like divergent thinking.

Poincare describes how mathematical solutions came to him in flashes while he was relaxing and not concentrating on the problem. He also describes how he understands mathematical demonstration: "the order in which the elements are placed is much more important than the elements themselves. If I have the feeling, the intuition, so to speak, of this order, so as to perceive at a glance the reasoning as a whole, I need no longer fear lest I forget one of the elements, for each of them will take its allotted place in the array...."

In light of the evidence and research on brain laterality, the processess reported by these creative individuals are surely examples of right hemisphere thinking.

Experimental studies provide further evidence that creativity is related to right hemisphere activity. A researcher named Martindale (1975) observed the type of brain waves produced during various tasks including an Alternate Uses test which requires creativity. He found that when attempting to perform a creative task, non-creative persons seem to use their brains in the same way as they do for other tasks such as an intelligence test. Creative individuals, on the other hand, suddenly show a big difference in brain patterns when they encounter a creative task. They seem to stop concentrating on the task and begin producing a large amount of

alpha brain waves, indicating a very relaxed, low-arousal mental state. In addition to producing more alpha, these individuals also show a different balance of brain activity between the two brain hemispheres. During relaxation, the pattern of alpha distribution between the two hemispheres is markedly different for people deemed highly creative and those described as medium or low creative. Creative people tend to produce rather equal amounts of alpha in both hemispheres while the medium creative people produced much more alpha in the right hemisphere than in the left. The more equal amount of alpha may indicate that creative people are using both modes of thought while the medium creative people use primarily the left hemisphere. People classified in the study as low creative showed very little alpha in either hemisphere perhaps indicating that they were too anxious.

Creativity, then, may involve mental relaxation and increased right hemisphere thinking. Concentration seems to be related to directed, left hemisphere thought while creativity requires more visualization and right hemisphere thought.

Learning Strategies

Many of the instructional and learning strategies currently in practice emphasize verbal and analytical thinking. These strategies include, for example, reading advance organizers and learning objectives; answering inserted questions, quizzes, and tests; summarizing or paraphrasing new concepts; re-organizing material and taking notes; surveying new information by skimming and scanning; and using verbal retrieval

strategies during recall. These various strategies probably require mostly left brain thinking. The research on brain laterality can be applied to educational processes to activate the lesser-used right side of the brain during learning to involve the whole brain in learning and thereby elicit more well-rounded learning. The following instructional and learning strategies may be used to elicit more right hemisphere thinking during learning.

Synthesis or Gestalt Instructions and Inducements. Simply telling learners to use more right hemisphere thinking by synthesizing information and perceiving the gestalt may seem somewhat far-fetched but, surprisingly enough, it seems to work. Edwards (1976) facilitated drawing performance by her students merely by instructing them to perceive the gestalt rather than being analytical when they draw. In that study, one group of her students was given verbal-analytic instructions before copying a photo while the other group received synthesis or gestalt instructions. The first group was told to pay attention to the details of the picture and to think of each part of the picture as meaningful or symbolic; these instructions presumably elicit left-hemisphere thinking. The gestalt instructions group, however, was told to look at the overall picture and think about proportions and how the various shapes and shadings relate to one another. The group receiving the gestalt instructions produced drawings that were much more similar to the photo being copied than did the verbal-analytic group. Edwards concluded that the gestalt instructions activated the right hemisphere, which is better suited

to a drawing task than the left hemisphere.

Another technique used by Edwards to "turn off" the dominate left hemisphere and elicit gestalt perception in her students was to have the students copy a drawing or picture upside down. She compared the drawings of a group of students who copied a drawing that was inverted to a group that copied the drawing in the normal orientation. The group that viewed and copied the picture upside down produced more accurate drawings than the other group. Edwards reasoned that students can no longer analyze a picture into its logical component parts when it is upside down so they focus less on the meaning of the picture and more on the perceptual or physical characteristics. For example, an inverted human figure is no longer perceived as being composed of meaningful parts such as a neck, head, eyes, mouth etc., but rather is viewed as a collection of lines and shapes that relate to the whole.

Although the picture inversion technique was successful in the field of art education, that technique does not have the applicability to other fields that a general synthesis-instructions technique has. There are currently some efforts to test the effects of synthesis instruction in science education and elementary reading but findings are not yet available. Some type of synthesis learning strategy should, theoretically, help learners in a wide variety of subject matter areas.

Imagery Instructions. One learning strategy that has had wide application to many different fields and learning tasks is imagery instructions. This technique, which presumably elicits right hemisphere

thinking, involves telling or training the learner to form vivid, mental images of what he or she is learning about. One very successful application of imagery instructions has been using imagery mnemonics to remember otherwise unrelated words or word pairs. Learners have demonstrated dramatic increases in memory power using imagery mnemonics. One such mnemonic system was developed by Lorayne and uses what he calls a "peg system" for remembering number-object pairs. The trick is to form an "interactive" mental image associating the object with Lorayne's picture-mnemonic for the number. For example, if you wish to associate the number six with the object "tree," you would try to mentally imagine some interaction between a tree and the picture-mnemonic for the number six, which is an elephant's trunk (the trunk curls into a 6). The interactive image might be an elephant holding a little tree in its trunk. The best interactive images, according to Lorayne and Lucas (1974), are bizzare or unique so a better image may be an elephant balancing on top of the tree. A non-interactive image would not help the learner remember. For example, thinking of an elephant standing next to a tree would not be as memorable. Many studies have demonstrated the effectiveness of interactive mental imagery in remembering words and word pairs.

A similar system of imagery mnemonics has been used successfully in language learning. Atkinson (1976) developed what he called the keyword method for learning foreign vocabulary. Rather than learning the words through repeated drill and practice, a student applies the keyword method only once to each word and saves a great deal of study time.

The keyword method is applied as follows: First, the student selects a keyword for the foreign word. The keyword is an English word that sounds like it is contained in the foreign word. For example, the keyword for the Spanish word "caballo" could be "cob" because it sounds like the first syllable of the foreign word. Then the student creates a mental image using the keyword and the translation, which is "horse." The image should be interactive so the student may form a mental picture of a horse biting on a corn cob or smoking a corn cob pipe. When the student is later required to give the translation, he or she will think of the mental image and respond appropriately. Atkinson's students achieved remarkable results using this method.

Mental imagery also facilitates memory for school-like material such as instructional text passages (rather than single words or paired-associates). When learners are asked to generate strong, mental images for the material that they are reading or studying, they remember it better. This technique of merely instructing learners to use mental imagery has been used successfully with both adults and children. One exception is that using mental imagery does not really help the learner remember difficult material tha is new or totally unfamiliar. This exception is plausible since we cannot expect learners to be able to form mental pictures of concepts that they have absolutely no familiarity with.

A problem with trying to use mental imagery while reading is that the act of reading may interfere with being able to generate mental imagery. Several studies found that imagery use may be

more beneficial when the learners alternated the activities of reading or listening and mental imagery production. Rather than trying to mentally imagine concepts while reading, the learner should read a passage or section of a text and then stop to mentally imagine the important concepts.

Pictures. Research on imagery-eliciting strategies, reviewed by Lutz and Lutz (1978 , indicates that one effective strategy is to show learners a picture to illustrate the information that they are learning or to have them draw their own picture to illustrate the new concepts. Pictures are so much more memorable than words and can, therefore, be used to help learners remember verbal material. Many studies have compared visual memory to verbal memory and found that recognition memory for pictures seems almost limitless. People can be shown hundreds of photographs for just a few seconds duration and later be able to identify almost all of the pictures that they had seen from a mixture of new and previously-seen photos. Memory for words, on the other hand, is quite limited unless learning strategies are used.

Using pictures to aid verbal learning has been successful with several types of learners, subject matters, and tasks. Both children and adults benefit from seeing or drawing pictures to illustrate the verbal information. All types of learners benefit from pictorial strategies although high right-hemisphere ability people are helped most. Pictorial strategies have proven facilitative in a variety of fields including reading, math, science etc. And, finally, this strategy aids word learning, paired-associate learning, and new concept learning.

Several types of picture mnemonics have been used to facilitate paired-associate learning (Lutz and Lutz, 1977). These techniques aid vocabulary learning and are widely used in advertising to help consumers remember to associate some product with a particular brand. The most effective technique is called picture interaction and consists of pictorially depicting the items to be associated interacting in some way. Examples from advertising are most illustrative of this technique. The interactive picture for Arrow Pest Control is a dead bug that had been shot by an arrow. Jack's Camera Shop uses picture interaction in its logo, which shows a jack on a playing card holding a camera to his eye.

Another technique that uses picture mnemonics to aid paired-associate learning is called letter accentuation. When one word of the pair is not concrete or easily pictured, then only one letter from that word is used to make an interactive image. For example, the letter accentuation logo for Dixon Crane Company shows two cranes that cross to make the "x" in "Dixon."

A third technique is called inclusion and consists of pictorially embedding the characteristics of one item in the picture of the other item in the pair to be associated. Mullen Lumber Company uses inclusion by portraying the letters in "Mullen" as made of lumber boards.

Pictures are valuable when learning new concepts and studying instructional material. One experiment compared a computer-assisted instruction (CAI) lesson about how a simple battery works which contained graphic analogies to an all-verbal version of the lesson. Students

who viewed animations of the various chemical reactions and visual analogies of the electrochemical concepts remembered more and performed better on the post-test than did the students who received the same information verbally. Students who saw the animated graphics also reported that they enjoyed the learning experience more than the other group.

Analogies. Giving a learner analogies or instructing learners to generate their own analogies between the new concepts being learned and prior knowledge is another strategy that may elicit right hemisphere thinking. It requires learners to use divergent rather than convergent thinking and this type of thinking is related to right hemisphere use. The value of both verbal and visual analogies is emphasized in a creativity training program by Gordon (1961). He used the techniques of personal analogy, direct analogy, symbolic analogy, and fantasy analogy to facilitate learning of science concepts in his students. Personal analogy, for example, requires the learner to try to identify empathetically with a problem being studied until "new visual images grow out of the identification process." If students were trying to learn Ohm's Law, they would use this technique by trying to really feel how electricity flows through a circuit and encounters resistance. Gordon reports that his students achieved positive results by using these techniques.

There are several training programs in analogy strategies and they have produced beneficial effects in their students. One study, for example, trained college students in an introductory physics course to compare and to contrast new material with their prior, related

knowledge. Students with this training learned more from new instructional material in physics and also remembered more when applying this learning strategy to fields unfamiliar to them such as accounting. Other training programs have also had success at teaching learners to write out similarities and contrasts between new concepts they are learning and related, prior knowledge.

Chunking. It has been suggested that people can hold only a limited number of information units or "chunks" in short-term memory at any one time, that number ranging from 5 to 9 bits of information. For example, most people can temporarily remember a 7 digit phone number but probably cannot remember several unfamiliar phone numbers simultaneously without memorizing them or using strategies to transfer them to long-term memory. Although the number of chunks is limited, the information chunks may range in complexity from, for example, a single letter or number to a complex picture. By increasing the complexity of the chunks, one is in effect increasing the amount of information in short-term memory.

Chunking consists of combining formerly separate items or bits of information together into a new unit or group. If the items fit together in some way [illegible] pattern, this pattern becomes the new unit of information [illegible] component parts. Chunking involves using the right [illegible] gestalt rather than continuing to focus on each [illegible]

Chunking [illegible] use the power of memory as demonstrated by a study which compared chess experts to novices on the basis

of their ability to remember locations of chess pieces on a chess board. The task in this study was to remember the location of the various pieces after briefly viewing them arranged in different ways on the chess board. When the chess pieces were arranged to look as if a game was in progress, chess experts were able to recall the location of many more pieces then were novices. However, when the pieces were just randomly placed on the board, the two groups did not differ in the number of pieces they could correctly re-locate. The fact that randomly-arranged boards are not better remembered by the experts indicates that their superior performance is not due simple to more powerful memories. Rather, it indicates that the experts must chunk chess pieces into meaningful patterns or groups that can be recognized as quickly as the novice recognizes each separate chess piece. When the board is randomly arranged, there are no meaningful patterns and the expert must look at each piece separately just as the novice does.

Chunking is a valuable learning strategy that can be applied to many fields. Reading performance, for example, can be greatly enhanced by using a chunking technique. There are a number of successful speed reading programs which help students achieve success in reading by training them how to chunk information while reading and how to avoid looking at every word or short, word phrase. Students learn through successive steps to perceive more and more words and phrases in one chunk so that they need fewer glances or fixations to read the same amount of material.

Another application of the chunking technique to learning is a method of mathematical calculation called chisanbop (Lieberthal, 1978).

The Korean term "chisanbop" means finger calculation method, which implies a slow, serial calculation method discouraged in the lower grades. This particular method, however, is faster than using an electronic calculator and helps the student understand the meaning of the operations performed. The secret of this method's success is that it allows the learner to chunk numerical information while a calculator must handle numbers and operators one at a time. A calculator can only accept a single piece of data such as a digit or operation at one time, but a human using this method can have simultaneous input as the following example illustrates. To enter the number "55" on a calculator, you must make 3 key presses (i.e. press the 5 key twice followed by some type of operator such as enter or addition). Using chisanbop, however, one movement is required. Since each finger and thumb is assigned a numerical value in chisanbop, any 2-digit number can be represented by simultaneously "pressing" the appropriate pattern of fingers. In the case of "55", both thumbs are pressed since one thumb has the value of 50 and the other has the value of 5. To substract "40" from our number, you must again press 3 keys on an electronic calculator. Using chisanbop, only one movement is required: the left index finger is pressed while the left thumb is simultaneously raised (since the finger's value is 10). The student merely "reads" the resultant number. With practice this method can actually be used to perform complicated calculations. Using an abacus is probably similar to this method in that the learner chunks digits and learns to handle numbers and operations as patterns. With much practice, these external aids may become internalized so that the person can eventually

mentally imagine the patterns.

Miscellaneous Concrete Learning Activities. There are so many concrete learning activities specific to a particular subject matter or learning task that it is impossible to list them all, but a few examples will be discussed. Science education often makes use of concrete learning activities such as demonstrations, experiments, and other "hands-on" activities. One example of a concrete activity suggested for students learning how a battery works is to actually construct a battery using simple, common materials. It is called the 11-cent battery because a copper penny is used for the anode and a silver dime serves as the cathode. The electrolyte consists of a blotter soaked with salt water. By constructing this battery that generates current, the student will better remember the battery parts and processes because he or she manipulated concrete examples of these otherwise abstract concepts.

One type of concrete learning activity that can be very cost effective is simulation. Conducting an actual experiment or demonstration may be costly both in terms of time and money while a simulation can probably produce the same learning outcomes with reduced costs. A system for computer-assisted instruction (Bitzer, 1976) that I worked with has a number of simulations in many subject matter areas. For example, one simulation allowed young students learning math fractions to divide up (simulated) pizzas into fractional pieces and distribute the pieces as directed (i.e. give ½ to John). In another lesson, a simulated laboratory for college biology students who are

learning the principles of genetics allows the students to cross various strains of fruit flies and view the characteristics of resultant generations. In an actual laboratory experiment, the results of the crossings would take much longer and the student may waste weeks if an error in pairing were made. Simulation may save materials as well as time. A laboratory simulation in chemistry allows the learners to perform a simulated titration experiment. The student uses no actual beakers, or solutions but the same principles and concepts are learned via the simulation.

Implications for Curriculum and Evaluation

Two basic questions that a curriculum decision-maker asks are what should be taught and what can be taught. To determine what should be taught, the curriculum decision-maker conducts a needs assessment that reveals the needs of learners, determines what subject-matter specialists say should be taught, and considers what society wants taught. The resultant needs are subjected to both a philosophical and a psychological screen before final curriculum decisions are made. An awareness of brain laterality should impact the curriculum decision-maker's actions at all phases of the process.

Needs Assessment. In making curricular decisions, various data sources should be considered starting with the learners themselves. With a growing awareness of the current over-emphasis on analysis and logical thought, students may feel a need to develop their ability in analogical thought. They may want to acquire more

of an appreciation for the arts. Subject-matter specialists and other educational professionals may emphasize the need for synthesis in addition to analysis during learning. And, finally, our society could begin to feel that a majority of the people rely too heavily on left-hemisphere thinking as opposed to right-hemisphere thinking and, therefore, feel a need to develop the synthetic-analogical skills.

Philosophical Screen: What should be taught? Regardless of the philosophy that the decision-maker adopts, the evidence of brain laterality can impact philosophical screening as the next few examples illustrate.

According to philosophical orientations such as perennialism and academic rationalism, the primary function of education is intellectual development so that a curriculum which stresses verbal ability to the almost total exclusion of spatial and imaginal ability is failing to develop a large part of the intellect. The findings on brain laterality imply that a liberal education is not as encompassing as it would seem to be since not all potential abilities are developed. Just as reading and writing go together, appreciation as well as production of the arts should be included in the curriculum.

Adopting a social reconstructionism screen, one could content that society would be better off with individuals who were more well rounded in terms of their mental abilities. Cognitive skills such as analyzing, classifying, and sequencing are stressed by proponents of psychological cognitivism. The addition of other cognitive skills to the curriculum such as divergent thinking, imagination, synthesis,

intuition, and analogy can pass both philosophical screens. Individuals in our society are becoming increasingly narrow and specialized and there is a need for synthesizers. A curriculum which developes right hemisphere abilities is needed.

Psychological Screen: What can be taught? In determining the feasibility of the curricular goals, one must consider the difficulty of the task or goal and the learner's aptitude or ability to achieve the goal given the situation. The implications of brain laterality for determining what can be taught are that a) task difficulty may be altered greatly by using strategies discussed in the previous section and b) the feasibility of a curriculum goal depends on individual differences in learner aptitude. Tasks that were once thought to be quite difficult are now known to be quite easy when the learner uses the appropriate strategy such as imagery or chunking. There are many popular books available which tell how to increase memory dramatically by using such techniques. Therefore, curriculum goals which may have seemed infeasible may become attainable.

The final implication of brain laterality for determining if curricular goals can be achieved is that the feasibility of goals varies with different learners. An objective which requires analytic learning may be readily achieved by a left-hemisphere dominant learner but may be quite difficult for a right-hemisphere dominant thinker. Individual differences in brain laterality preferences should be considered when formulating goals for the learner as well as when prescribing instructional and learning strategies. Students with high spatial ability, for example, should use strategies that match

their cognitive style and capitalize on their strength such as imagery and picture drawing. Research on aptitude-by-treatment interactions indicates that students benefit from a treatment that matches their natural style and ability but may not learn if the inappropriate teaching method is used. There is no one best teaching method or learning strategy. An objective and method of achieving that objective must be matched to the student's ability.

Evaluating "Other" Learning Outcomes. The effectiveness of instruction must be viewed relative to the way learning outcomes are assessed. Tests of comprehension are often only verbal and analytical, which would mean that only left-hemisphere dominated learning is being assessed. Tests that require synthesis in addition to analysis should provide a better indication of just what the person has learned. A study discussed earlier found that the type of retrieval task determines the information retrieved in split-brain patients. The reported information stored in the right brain when asked to point and reported different information that had been sent to the left hemisphere when asked to verbally analyze what they saw. The type of retrieval task required of normal learners may produce similar differences; learners may have information stored visually that they find difficult to verbalize, for example.

Conclusion

This paper has attempted to summarize briefly the research findings on brain laterality and outline how these findings may apply to the

field of education. The findings of the research on brain laterality can help us re-conceptualize learning and creativity as ways of thinking that should include both types of thinking: logical and analogical. Adopting a view of mental abilities that excludes right-hemisphere abilities is too restrictive; intelligence must be enlarged to include other abilities than verbal and logical. A number of techniques can be used to activate the lesser-used right side of the brain. When these techniques are used along with the many verbally-oriented learning strategies, tremendous gains in learning effectiveness and efficiency should result. Finally, other aspects of education such as curriculum decision making and evaluation are affected by the findings concerning brain laterality. New needs arise relative to the right hemisphere and these needs direct the generation of learning objectives. Goals that may have previously been considered too difficult may be attainable by using new learning strategies. These goals should not be limited to learning and thinking related to the left hemisphere but should be geared to other types of outcomes that are related to the right hemisphere. Evaluating only the verbal and analytical outcomes of learning may fail to reveal the full effects of instruction. Both types of thinking are important during learning and both types of achievement should be assessed. All aspects of the educational process can be impacted by the findings on brain laterality.

References

Bitzer, D. L. The wide world of computer-based education. In M. Rubinoff & M. Yovits (Eds.), Advances in computers Vol 15. New York: Academic Press, 1976.

Edwards, B. An Experiment in Perceptual Skills in Drawing. Unpublished doctoral dissertation, University of California, Los Angeles, 1976.

Gordon, W. J. J. Synectics. New York: Harper and Brothers, 1961.

Lieberthal, E.M. Chisanbop; Finger Calculation Method. New York: Van Nostrand Reinhold Col, 1978.

Lorayne, H. and Lucas, J. The Memory Book. New York: Stein and Day, 1974.

Lutz, K. A. and Lutz, R. J. Imagery-eliciting strategies: Review and implications of research. In H. K. Hunt (Ed.), Advances in Consumer Research Vol. V. Provo, Utah: Association for Consumer Research, 1978.

Martindale, C. What makes creative people different. Psychology Today, 1975, 9, 44-50.

Wittrock, M. C. et al. The Human Brain. Englewood Cliffs, N. J.: Prentice-Hall, 1977.